CLAIMS

What is claimed is:

1. A magnetic element capable of storing multiple bits comprising:

a first pinned layer, the first pinned layer being ferromagnetic and having a first pinned layer magnetization, the first pinned layer magnetization being pinned in a first direction;

a first nonmagnetic layer, the first nonmagnetic layer being conducting;

a first free layer, the first nonmagnetic layer residing between the first pinned layer and the first free layer, the first free layer being ferromagnetic and having a first free layer magnetization;

a connecting layer;

a second pinned layer, the second pinned layer being ferromagnetic and having a second pinned layer magnetization pinned in a second direction, the connecting layer residing between the second pinned layer and the first free layer;

a second nonmagnetic layer, the second nonmagnetic layer being conducting;

a second free layer, the second nonmagnetic layer residing between the second pinned layer and the second free layer, the second free layer being ferromagnetic and having a second free layer magnetization;

wherein the magnetic element is configured to allow the first free layer magnetization and the second free layer magnetization to change direction due to spin transfer when a write current is passed through the magnetic element.

2. The magnetic element of claim 1 wherein the first free layer is configured to be written using a first write current and a second write current, the first write current in a first current direction, the second current in a second current direction and wherein the second free layer is configured to be written using a third current write current and a fourth write current, the third write current in the first current direction, the fourth write current in the second direction, the first write current, the second write current, the third write current and the fourth write current being different.

3. The magnetic element of claim 1 wherein the connecting layer is an antiferromagnetic layer adjacent to the second pinned layer and the first pinned layer.

4. The magnetic element of claim 1 wherein the connecting layer, the first pinned layer, and the second pinned layer form a synthetic antiferromagnet including hard magnetic layer /Ru/hard magnetic layer or hard magnetic layer/Ru/soft magnetic layer.

5. The magnetic element of claim 1 further comprising:

an antiferromagnetic layer adjacent to the second pinned layer, the antiferromagnetic layer for pinning the second pinned layer magnetization in the second direction, the connecting layer being adjacent to and between the antiferromagnetic layer and the first free layer.

6. The magnetic element of claim 1 wherein the first free layer is a synthetic layer.

7. The magnetic element of claim 1 wherein the second free layer is a synthetic layer.

8. The magnetic element of claim 1 wherein the first pinned layer is a synthetic layer.

9. The magnetic element of claim 1 wherein the second pinned layer is a synthetic layer.

10. The magnetic element of claim 1 wherein the first nonmagnetic layer is an insulating barrier layer that allows charge carriers to tunnel between the first pinned layer and the first free layer.

11. The magnetic element of claim 1 wherein the second nonmagnetic layer is an insulating barrier layer that allows charge carriers to tunnel between the second pinned layer and the second free layer.

12. The magnetic element of claim 1 wherein the connecting layer is conductive.

13. The magnetic element of claim 1 further comprising:

a barrier layer; and

a third pinned layer, the barrier layer residing between the third pinned layer and

the first free layer, the barrier layer allowing tunneling of charge carriers between the third pinned layer and the first free layer, the third pinned layer having a third pinned layer magnetization pinned in a third direction.

14. The magnetic element of claim 13 wherein the first direction is antiparallel to the third direction.

15. The magnetic element of claim 13 wherein the first free layer is a synthetic free layer.

16. The magnetic element of claim 15 wherein the first direction is parallel to the third direction.

17. The magnetic element of claim 13 further comprising:

a second barrier layer; and

a fourth pinned layer, the second barrier layer residing between the fourth pinned layer and the second free layer, the second barrier layer allowing tunneling of charge carriers between the fourth pinned layer and the second free layer, the fourth pinned layer having a fourth pinned layer magnetization pinned in a fourth direction.

18. The magnetic element of claim 17 wherein the second direction is antiparallel to the third direction.

19. The magnetic element of claim 18 wherein the first direction is parallel to the third direction.

20. The magnetic element of claim 17 wherein the second free layer is synthetic.

21. The magnetic element of claim 17 wherein the second pinned layer is synthetic.

22. The magnetic element of claim 17 wherein the third pinned layer is synthetic.

23. A magnetic element capable of storing multiple bits comprising:

a first dual spin tunnel/valve structure including a first pinned layer, a first nonmagnetic spacer layer, a first free layer, a first barrier layer, and a second pinned layer, the first nonmagnetic spacer layer residing between the first pinned layer and the first free layer, the first barrier layer residing between the first free layer and the second pinned layer;

a connecting layer; and

a second dual spin tunnel/valve structure including a third pinned layer, a second nonmagnetic spacer layer, a second free layer, a second barrier layer, and a fourth pinned layer, the second nonmagnetic spacer layer residing between the third pinned layer and

the second free layer, the second barrier layer residing between the second free layer and the fourth pinned layer.

24. The magnetic element of claim 23 wherein the magnetic element is configured to allow the first free layer magnetization and the second free layer magnetization to change direction due to spin transfer when a write current is passed through the magnetic element.

25. The magnetic element of claim 23 wherein the first dual spin tunnel/valve structure is configured to be written using a first write current and a second write current, the first write current in a first current direction, the second current in a second current direction and wherein the second dual spin tunnel/valve structure is configured to be written using a third current write current and a fourth write current, the third write current in the first current direction, the fourth write current in the second direction, the first write current, the second write current, the third write current and the fourth write current being different.

26. The magnetic element of claim 23 wherein the connecting layer is an antiferromagnetic for pinning the second pinned layer magnetization and the third pinned layer magnetization.

27. The magnetic element of claim 23 wherein the connecting layer, the second pinned layer, and the third pinned layer form a synthetic antiferromagnetic hard including

magnetic layer/Ru/hard magnetic layer or soft magnetic layer/Ru/soft magnetic layer.

28. The magnetic element of claim 23 wherein the connecting layer is an antiferromagnetic for pinning the second pinned layer magnetization and the fourth pinned layer magnetization.

29. The magnetic element of claim 23 wherein the connecting layer is a synthetic antiferromagnetic hard/Ru/hard or soft/Ru/soft layer sandwiched between the second and fourth pinned layers

30. The magnetic element of claim 23 wherein the first free layer is synthetic.

31. The magnetic element of claim 23 wherein the second free layer is synthetic.

32. The magnetic element of claim 23 wherein the first pinned layer is synthetic.

33. The magnetic element of claim 23 wherein the second pinned layer is synthetic.

34. The magnetic element of claim 23 wherein the third pinned layer is synthetic.

35. The magnetic element of claim 23 wherein the fourth pinned layer is synthetic.

36. A method for programming a magnetic element capable of storing multiple bits comprising the steps of:

if a first state is to be written, passing a first current through the magnetic element, the magnetic element including a first pinned layer, a first nonmagnetic layer, a first free layer, a connecting layer, a second pinned layer, a second nonmagnetic layer, and a second free layer, the first pinned layer being ferromagnetic and having a first pinned layer magnetization, the first pinned layer magnetization being pinned in a first direction, the first nonmagnetic layer residing between the first pinned layer and the first free layer, the first free layer being ferromagnetic and having a first free layer magnetization, the second pinned layer being ferromagnetic and having a second pinned layer magnetization pinned in a second direction, the connecting layer residing between the second pinned layer and the first free layer, the second nonmagnetic layer residing between the second pinned layer and the second free layer, the second free layer being ferromagnetic and having a second free layer magnetization, the magnetic element being configured to allow the first free layer magnetization and the second free layer magnetization to change direction due to spin transfer, the first current being sufficient to align the first free layer magnetization parallel to the first pinned layer magnetization and to align the second free layer magnetization parallel to the second pinned layer magnetization;

applying at least a second current through the magnetic element, the at least the second current leaves the first free layer magnetization parallel to the first pinned layer magnetization and aligning the second free layer magnetization antiparallel to the second pinned layer magnetization;

if a third state is to be written, applying at least a third current through the magnetic element, the at least the third current aligning the first free layer magnetization antiparallel to the first pinned layer magnetization and aligning the second free layer magnetization antiparallel to the second pinned layer magnetization; and

if a fourth state is to be written, after applying the first current, applying at least a fourth current through the magnetic element, the at least the fourth current leaves the first free layer magnetization antiparallel to the first pinned layer magnetization and aligning the second free layer magnetization parallel to the second pinned layer magnetization.

37. The method of claim 31 wherein the first free layer is configured to be written using a first write current in a first current direction and a second write current in a second current direction through the magnetic element, wherein the second free layer is configured to be written using a third write current in the first current direction and a fourth write current in the second current direction through the magnetic element, the third write current being less than the first write current, the fourth write current being less than the second write current, the first current being in the first current direction and being greater than the first write current and the third write current;

wherein the at least the second current includes a fifth current applied in the first current direction followed by a sixth current applied in the second current direction, the

fifth current being greater than the first write current and the third write current, the sixth current being less than the second write current and greater than the fourth write current;wherein the at least the third current includes a seventh current in the second current direction followed by an eighth current in the first current direction, the seventh current being greater than the second write current and the fourth write current, the eighth current being less than the first write current and greater than the third write current; and

wherein the at least the fourth current includes a ninth current in the second current direction, the ninth current being greater than the second write current and the fourth write current.

38. A method for providing magnetic element capable of storing multiple bits comprising the steps of:

providing a first pinned layer, the first pinned layer being ferromagnetic and having a first pinned layer magnetization, the first pinned layer magnetization being pinned in a first direction;

providing a first nonmagnetic layer;

providing a first free layer, the first nonmagnetic layer residing between the first pinned layer and the first free layer, the first free layer being ferromagnetic and having a first free layer magnetization;

providing a connecting layer;

providing a second pinned layer, the second pinned layer being ferromagnetic and having a second pinned layer magnetization pinned in a second direction, the connecting layer residing between the second pinned layer and the first free layer;

providing a second nonmagnetic layer;

providing a second free layer, the second nonmagnetic layer residing between the second pinned layer and the second free layer, the second free layer being ferromagnetic and having a second free layer magnetization;

wherein the magnetic element is configured to allow the first free layer magnetization and the second free layer magnetization to change direction due to spin transfer when a write current is passed through the magnetic element.

39. The method of claim 38 wherein the first pinned layer, the first free layer, the second pinned layer and the second free layer are defined in a single step.

40. The method of claim 38 wherein the first pinned layer and the first free layer are defined in a first step and the second pinned layer and the second free layer are defined in a second step separate from the first step.

41. The method of claim 38 further comprising the step of:

providing an additional spin tunneling junction.

42. The method of claim 38 further comprising the step of:

providing an additional dual spin tunnel/valve structure.

43. A method for providing a magnetic element capable of storing multiple bits comprising the steps of:

providing a first dual spin tunnel/valve structure including a first pinned layer, a first nonmagnetic spacer layer, a first free layer, a first barrier layer, and a second pinned layer, the first nonmagnetic spacer layer residing between the first pinned layer and the first free layer, the first barrier layer residing between the first free layer and the second pinned layer;

providing a connecting layer; and

providing a second dual spin tunnel/valve structure including a third pinned layer, a second nonmagnetic spacer layer, a second free layer, a second barrier layer, and a fourth pinned layer, the second nonmagnetic spacer layer residing between the third pinned layer and the second free layer, the second barrier layer residing between the second free layer and the fourth pinned layer.

44. The method of claim 43 wherein the first dual spin tunnel/valve structure and the second dual spin tunnel/valve structure are defined in a single step.

45. The method of claim 43 wherein the first dual spin tunnel/valve structure is defined in a first step and the second dual spin tunnel/valve structure are defined in a single step.

46. The method of claim 43 wherein the first dual spin tunnel/valve structure is configured to be written using a first write current and a second write current, the first write current in a first current direction, the second current in a second current direction and wherein the second dual spin tunnel/valve structure is configured to be written using

a third current write current and a fourth write current, the third write current in the first current direction, the fourth write current in the second direction, the first write current, the second write current, the third write current and the fourth write current being different.

47. The method of claim 43 further comprising the step of:

providing a third dual spin tunnel/valve structure on the second dual spin tunnel/valve structure.

48. The method of claim 47 further comprising the step of:

providing a connecting layer between the second dual spin tunnel/valve structure and the third dual spin tunnel/valve structure.